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OF THE

ROYAL ASTRONOMICAL SOCIETY.

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W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Albert Fowell Austin, Luton, Bedfordshire;
Algernon Sidney Bicknell, Staplefield Place, Crawley, Sussex;
Rev. George Burgess, The Woodlands, Urmston, Manchester;
Démétrius Eginitis, D. ès Sc., Observatoire, Paris;
George Richard Farncombe, M.A., 40 Belgrave Street, Birmingham;
Vernon Edwin Knocker, Castle Hill House, Dover;
Benjamin Noble, F.S.S., Gloucester House, Newcastle-on-Tyne;
Henry William Lloyd Tanner, M.A., 29 Clive Road, Penarth, South Wales;
R. Lethbridge Tapscott, Assoc. M.Inst.C.E., F.G.S., F.R. Met. Soc., 41 Parkfield Road, Liverpool;
William Grasett Thackeray, Royal Observatory, Greenwich,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election, the names of the proposers from personal knowledge being appended:—

The Rev. S. R. Craig, B.A., LL.B., F.S.S., The Rectory, Moville, Londonderry (proposed by W. J. Lancaster);
James Edward Keeler, B.A., Astronomer of the Lick Observatory (proposed by E. E. Barnard).

The Photographic Apparatus of the Great Equatorial of the Lick Observatory. By Edward S. Holden, LL.D., Director of the Lick Observatory, Foreign Associate.

The Lick Observatory has just received from the makers of the great telescope the compound slide-rest, which is to carry the negative plate of the Great Equatorial. It may be of interest to state the problem which this machine is destined to solve and to briefly describe its arrangements.

Accordingly I have asked Mr. Barnard to photograph our photographic appliances (see figure), which he has kindly done.

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The problem which was early presented to us in the use of the photographic lens of the great telescope was this:—

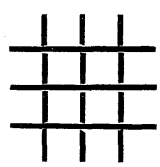
The tube of the telescope (and very likely the declination axis) is subject to slight flexures, and all long exposures therefore produced short irregular lines instead of round dots for the star images. The focal length of the photographic lens is 47 feet 6·2 inches (aperture 33 inches), and one second of arc is 0·0028 inches on the plate ($1' = 0{\cdot}166$, $1^\circ = 9{\cdot}948$ inches).

So great a focal length makes a very slight *angular* displacement of the image readily visible on the plate as a considerable *linear* distortion.

Hence it was indispensable to provide some means of moving the plate by hand so as to keep the star images fairly round. The first experiments in photography were made by Mr. Burnham in August 1888, and the pictures of the Moon which have hitherto been made here are all by him. During September 1888 Professor Schaeberle constructed a compound slide-rest out of wood, by means of which experiments were made which fully showed that the method proposed would be entirely successful with an apparatus constructed out of metal. About the same time Mr. Common was kind enough to send me photographs of a very similar machine which he had adopted for his great reflector. (See *Monthly Notices*, R.A.S. vol. xlix. p. 297).

During January and February 1889 the final plan for our slide-rest was settled on, and it has been made by Messrs. Warner and Swasey in a highly satisfactory manner. In a few days it will be in place, and astronomical photography can be resumed here after a long and regrettable interval of lost time.

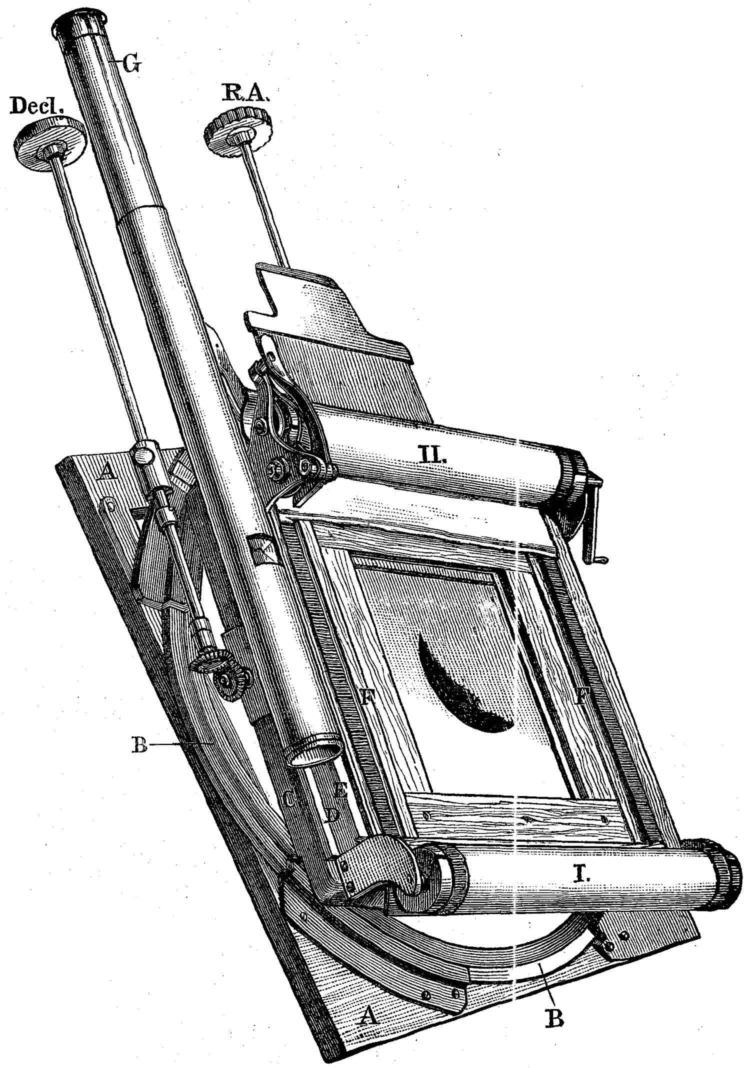
The general principle of the machine is as follows:—The negative plate is mounted on a slide-rest E, movable in right ascension; the slide-rest E together with the negative plate is movable in declination on a second slide-rest D. Attached to the right ascension slide-rest (E) is a guiding eyepiece G. The observer directs this eyepiece, which has a reticle plate of glass with wires as below,



upon some selected guiding star and then makes the exposure. As long as the star remains on the proper wire of the reticle the slides are left unchanged and the negative remains in its original place. As soon as the star leaves the wire the slides are moved by appropriate handles until the guiding star (and thus the negative) is brought back to its primitive position.

Such then is the general principle of the machine. In the apparatus for the Lick Observatory it was necessary to introduce one more complication, namely, to give the whole machine a rotation of some 40 degrees in its own plane. The focus of the photographic lens is 10 feet 4·2 inches nearer the object-glass than

the visual focus. Hence the photographic plate must be reached through a *port* cut in the side of the great tube. (This port is 23 by 12 inches.) The most convenient place for such a port is in the side of the tube nearest to the declination axis; but when the telescope was delivered to the astronomers I found that this port had been cut at random and without consideration in a different place, so that the negative plate when inserted would have its longest dimension inclined some 30 degrees to the parallel. Hence it was convenient to give the plate and the whole apparatus a motion of rotation of 30 degrees in its own plane.



Compound Slide-Rest, for carrying the Negative Plate of the 36-inch Equatorial.

A reference to the cut will make the following description plain:—The negative of the Moon is on an 8×10 plate. Hence the scale of the figure is easily determined. The machine was

delivered to us beautifully lackered. It has, however, been ruthlessly painted a dull black.

The lowest square frame of the apparatus I call plate A. This is $23 \times 24\frac{3}{4}$ inches, and in its centre is a square hole $19\frac{1}{2}$ inches on a side. When the apparatus is put in place this plate A is supported by four rods inside the telescope tube and parallel to its axis. A motion along these rods serves to focus the plate. The system of four rods has a thwart adjustment, so that the plate can be made normal to the incident ray. Above the plate A is a circular ring, B, about 23·7 inches outside and 21·5 inside diameter.

This ring is movable in its own plane through about 41 degrees by a handle which is just visible behind the guiding eyepiece. The ring can be clamped in any desired position. Rigidly fastened to ring B is a square frame C, $17\frac{1}{2}$ inches outside, containing a square hole $14\frac{1}{2}$ inches on a side. The declination slide, D, is $17\frac{1}{2}$ inches square outside, and also has a hole $14\frac{1}{2}$ inches square cut in its centre. This slide can be moved over a distance of about six or seven minutes of arc by a screw of 30 threads to the inch (1 revolution = about 10″). The smooth wooden head to the handle of this screw is seen next the guiding eyepiece. The right ascension slide E moves on the declination slide by a similar screw. The roughened handle of this screw is seen above, to the right of the guiding eyepiece.

The right ascension slide contains a hole $12\frac{1}{4} \times 14\frac{1}{4}$ inches ($1° \ 14' \times 1° \ 26'$), and this is the largest photographic field available, so that nothing like the whole of the nebula of *Andromeda*, for example, can be photographed at one time. This sacrifice of field was necessary. As the particular advantage of our long-focus lens is to produce negatives suitable for *measures*, this restriction of field is not so regrettable as it might be in another instrument of shorter focus.

Usually a brass box, F, rests inside of E to take the wooden plate-holders. This box has a free aperture of $14 \times 12\frac{1}{4}$ inches. When the telescope is not used for photography the cone of (visual) rays passes through the centre of this hole. Two wooden plate-holders for 11×14 plates fit directly into the brass box, F.

A wooden carrier, of the right size to be taken by the brass box, F, and containing an 8×10 plate-holder is shown in place, and I have laid in it a negative of the Moon taken (in the focus) August 13, 1888. This Moon is 5·2 inches in diameter.

Above the whole machine is the exposing apparatus. This consists of two cylinders, I (the lowest in the cut) and II. They are connected by tapes along the edge of the slit. Part of the curtain is rolled on I and part on II in the cut, which shows the disposition of things for a time-exposure. The lower roller, I, contains a strong spring. If the thumb-piece on the upper roller is touched, the curtain will fly down (in the cut) and cover the aperture. For an instantaneous exposure the upper roller must be rotated (by the small crank at its end) until the lower curtain covers the aperture. The slide of the plate-holder must then be drawn. At the proper time the thumb-piece must be

touched, when the curtain will fly down, carrying the open part of the curtain past the plate, and quickly covering the plate with that portion of the curtain shown rolled up on the upper roller.

The guiding eyepiece, G, is a positive eyepiece giving a power of about 500 diameters on the photographic objective. It can be moved bodily in the direction of its length, and clamped in any position. A beam from the objective is received on the prism (near its lower end in the cut) and brought to a focus on its glass reticle, previously described. The wires of this reticle are heavy enough to be seen without illumination. If any light is needed it can be had by means of luminous paint on the reticle itself.

For enlarging, it is necessary to slip a board and tube (not shown in the cut) into the brass box, F, where the negative now is. The brass tube takes all our enlarging lenses. These are about 2 inches aperture and 14 inches focus, giving direct enlargements near the *visual* focus of 7 or 8 times. A 4×5 double plate-holder is used for this purpose.

It will be seen from what goes before that the process of taking a satisfactory negative with the great telescope is not a simple one. Let us suppose that a plate of the Pleiades of two hours' exposure is required. The telescope must be set, the dome turned, the driving clock wound, set in motion, and the control put on. A high step-ladder must be moved so that the observer sitting on its top can look into the guiding eyepiece. The plate is to be inserted and the slide drawn; the whole photographic slide-rest must be rotated till the parallel of declination is in the same direction as the edge of the plate, and the curtain must be withdrawn for a time-exposure, after a suitable guiding-star has been chosen. The observer sits (helpless) on the top of his high ladder, while a second observer must keep the elevating floor at the right level, see that the telescope points fairly centrally through the slit, and watch for the proper times to move the high step-ladder, so as to allow the first observer as nearly a comfortable position as is practicable. All this must be done in a dark dome, where only the feeblest red light is permissible.

Exposures longer than two hours can only be made by interruptions for winding up the clock weight (of 600 lbs.), which only runs for that period. The difficulties are considerable, and the fatigue and labour are great.

On the other hand the advantages gained are immense. Photographs of the Moon, nebulæ, stars, and planets can be had on a scale of 1 minute of arc equal $\frac{16}{100}$ of an inch. These photographs can be quickly measured on our measuring-engine with an accuracy *at least* equal to the best heliometer measures. I think there is very little doubt that a distance of $3000''$ can be measured with an accidental error of not much above $\frac{1}{10}$ of a second; and hence the photographic determination of parallax should be a comparatively easy matter, provided that constant errors are avoided by taking three or four plates each night. I

have as yet had only a limited opportunity to study our negatives.* I find, however, that an eyepiece of one inch equivalent focus can be used with advantage on our best Moon negatives. This corresponds to a magnifying power of 570 diameters. That is, it is practicable for an observer to sit in his study and to examine the lunar surface with a magnifying power of 570 diameters as often and as long as he pleases. Even more than this is true. Mr. Barnard has been kind enough to make positive enlargements on glass for me, which show the Moon twice as large as in the principal focus. An eyepiece of one inch equivalent focus is not too high to examine some features of these enlargements (and as they are *positives* they show the surface in its true light and colour). Thus it is practicable to see the lunar surface under excellent definition, and with a power of more than 1100 diameters, whenever one pleases and as long as one pleases.

I have no hesitation in saying that a study of our Moon negatives alone is capable of giving more information regarding the lunar surface than has been obtained by all the laborious years of observation by the most famous observers—Mädler, Lohrmann, Schmidt, and others now living.

It is simply necessary to study *two* sets of negatives, the second being necessary as a control on the first. Lest the above may seem to be too sanguine I will give one discovery I have lately made on our Moon negative of August 14, 1888.

It is well known that Mädler (and others) have mapped the walls of the Hyginus rill crossing the floor of the Hyginus crater. The observation is a delicate one and can only be made when the Sun is shining nearly in the direction of the preceding branch of this rill. Although this feature has often been mapped I think it has seldom been observed.

The walls inside the crater are hardly more than 1000 to 2100 yards apart, and their bright tops are not more than 200 to 220 yards wide. Yet I see these walls entirely well in the positive enlargement mentioned. From this single example it is possible to form a judgment of the results which a competent selenographer could draw from a suitably selected series of our Moon negatives. It is my intention to obtain such series as soon as practicable, and I shall offer a set, in the name of the Lick Observatory, to the Royal Astronomical Society in the hope that some "lonely and athletic student" may be willing to devote the two or three years necessary to their thorough and exhaustive study. It is not possible with the force at the disposition of the Lick Observatory to undertake more than the production of the materials for such a study. The study itself must, for the present at least, be left to others.

Lick Observatory, Mount Hamilton:
1889 *November* 23.

* See, however, a paper by Dr. Elkin in the *Astronomical Journal*, vol. ix. p. 35.